Using Smart Controlled AC and Ceiling Fan to Save Energy

Pin-Hung Wang[1], Jui-Yen Lin[2]
Department of Architecture, Kao Yuan University, Kaohsiung, Taiwan
[1]t60038@cc.kyu.edu.tw, [2]xryan19891207@gmail.com

Abstract. *This research aimed to explore the energy savings through the use of smart control as well as ceiling fan in intelligent building. As the energy consumption of air-conditioning (AC) accounts for about 40% of total residential energy, therefore, applying smart control system to the use of AC to achieve the effects of comfy and energy savings should be able to generate positive effect for the energy consumption of overall residential. This study used the smart control system in the intelligent building lab to transmit message to AC for its implementation of next operating step through the indoor temperature sensor in order to achieve energy saving effect.*
Keywords. *Intelligent building; smart control; energy saving; ZigBee; smart living.*

INTRODUCTION

This study focused on the exploration of the smart controlled AC (Air Conditioner) and ceiling fan, using the lab of intelligent building, in order to achieve the objective of energy saving. Although each country has different definition about intelligent building, all of their basic objectives are about the same. Intelligent building combines structure, system, service and operation management to create the most optimal combination and process for the construction of highly efficient, excellent function and comfortable buildings. Therefore, intelligent building must be able to satisfy users' needs, control easily, save energy, improve management effectiveness and clarify information.

This study focused on the role of energy saving in intelligent building. Taiwan has started promoting the intelligent building mark since 2004; however, over the eight years, there were only ten cases certificated, which is obviously lower compared to 359 green mark buildings in the past. Moreover, although intelligent building has already became a government policy and Taiwan's Executive Yuan has also started promoting intelligent building since 2006, using buildings as medium to integrate ICT and other related communication products to merge innovation and design application for the construction of new living environment, there are still few of successful intelligent buildings over these years. The main reason is not because of the technology problem, but of intelligent building requiring the cooperation of many different fields under cross-platforms. Without proper guidance, architects are difficult to carry out plans and designs.

In view of this, our study tried to use established intelligent building lab to conduct smart control of energy saving on available AC and ceiling fan in the space so as to explore the future development and direction for intelligent building by means of energy saving efficiency.

METHOD AND DEVELOPMENT OF INTELLIGENT BUILDING'S ENERGY SAVING

An overview of building spaces utilization shows that, the proportion of electricity used by AC accounts for about 40% of overall energy consumption, while lights and electric outlets takes up about
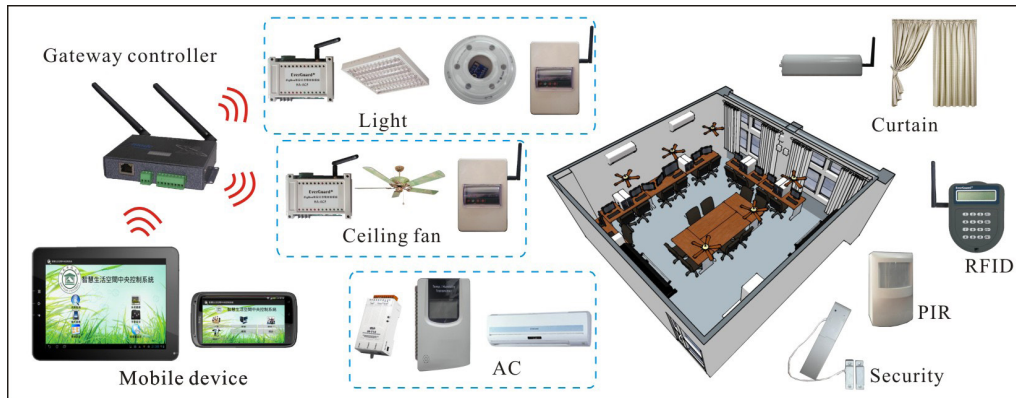
40% (Taiwan Power, 2006). This study applied smart control to AC and ceiling fan as a main planning direction to compare its energy saving effectiveness to traditional model as a reference for future intelligent building design.

For smart controlled AC and home appliance, they can be automatically adjusted by different approaches. ,For example, conducting smart control on living environment through EEG (Electroencephalography) (Lin et. al., 2010); using BCI(Brain Computer Interface) as biological and electric monitoring system to achieve the goal of active environment control; applying CPSs (Cyber Physical Systems)such as Bluetooth, ZigBee RF and infrared ray to carry out various communication protocols so as to convert a variety of different signals through a smart control box (Bai, 2012) using pyroelectric infrared sensor-based indoor location aware system (PILAS) as receivers (Kastner et. al., 2010) to monitor residents' activities, position, pattern, or health condition to provide the best living environment; handling complicated intelligent home equipment by the construction of low cost sensor and control systems based on ZigBee (Blesa et. al., 2009); using low budget stationary sensor to set up electronic nose for air quality monitoring (Zampolli et. al., 2004) to control the AC system for the best air flow; providing different colors of light by photovoltaic lighting systems developed in accordance with human cir-

cadian rhythms which meet human body's different biological needs so that to enhance living safety and comfort (Fu et.al., 2010); setting up multiple ZigBee moisture sensor around the indoor space to adjust the AC operation, improve living condition and reduce energy consumption through temperature and moisture data collection (Wang et. al. , 2010); , using the position method of BBM (Best Beacon Match) to smartly control living environment (Jin et. al., 2007), such system can control AC and lighting; using Smart phone as interface to monitor and control the living condition (Zhong et. al., 2011) (Li et. al., 2012) to replace remote control; using wireless of sensor networks to establish a physical environment for room control to adjust the use of electrical appliances automatically for the energy-saving effect through the data monitoring (Yeh, 2009).

RESEARCH METHODS

This study used ZigBee as the main transmitter to construct an environment and interface which are able to meet the requirements of smart control (Figure 1), in which the temperature and moisture in the room were detected by sensor, and such data were then transferred to AC through ZigBee's signals which will further advise AC about the next step to take through the intelligent control way so as to achieve the objective of energy-saving

Most homes' AC temperature control uses re-

Figure 2
AC controlle key functions.

turned air flow temperature as a basis to judge the next operating step of AC. Ceiling fan is a good way to condition the indoor air flow, and the room temperature can be rapidly and effectively reduced through the combination of these two appliances. However, f to adjust its frequency reduction or air conditioning running adjustment, the AC requires the room temperature reaches the pre-set value prior to starting its next operation. As the purpose of AC is not for cooling the entire room but for users only, therefore, this study used portable sensors near the users which can send back detected temperature data around the users back to AC every thirty seconds for AC's next operating preparation (such as reducing frequency, changing to air flow or reducing wind flow) without waiting for the reach of pre-set room temperature.

As the moisture sensor is portable and can respond the temperature near the users to AC immediately, it is with real time feedback feature and energy saving effect compared to the perception mode of traditional AC.

Most Home ACs are divided into fixed- and variable-frequency of window and wall mounted models. This study used fixed-frequency, wall mounted AC which has been used for five years and can be controlled through the remote control in terms of power switch, temperature, function, timer, fan speed, rhythm, sleeper, particularly the Fuzzy modes which uses the body perception condition as feedback data for AC's operating reference.

Although our lab controller only has 12 keys, the study's smart control model can simulate 32 controller functions, through different setups ways. For example, despite that there were only two temperature control keys (up and down), the temperature can be set from 17 °C to 31 °C; function key can control four modes of ATC, AC, dehumidification and fan; Fuzzy key has options of too hot, comfy, and too cold; fan key can set speed at high, mid, low, and auto; timing key can set time from 0.5 to12 hours; while most keys only have one function, all of them have on and off options. In sum, there are 48 different options in total (Figure 2) which are more than the 32 control functions set by this study. Owing to each brand's AC controller is different, how to choose the best control option in order to achieve energy saving and comfort will be the central topic of this research.

This research focused on room comfort as the main objective and, coupling with the energy saving objective, explored how to set up the best operation mode among the 32 simulated functions for energy saving and room comfort.

Most home AC (such as variable-frequency AC) will start to lower the compressor turn rate to save energy and maintain room temperature when the self-perception function detects the temperature of return air reaching the set temperature, and start to run the compressor again to low the temperature down once the room temperature raised to a certain degree. This study used fixed-frequency AC with compressor can only be operated with on or of function but cannot be operated as efficient and energy-saving as variable AC compressor in terms of maintain the indoor temperature through the change of frequency.

In this study, when the indoor temperature in the intelligent building reaches a preset limit, the controller will place to AC an order to implement next operation. Instead of by AC itself, it used the external sensor to detect the current room temperature and then issue the next operating order. Owing to that the study could only use the function key on remote controller key as simulation object
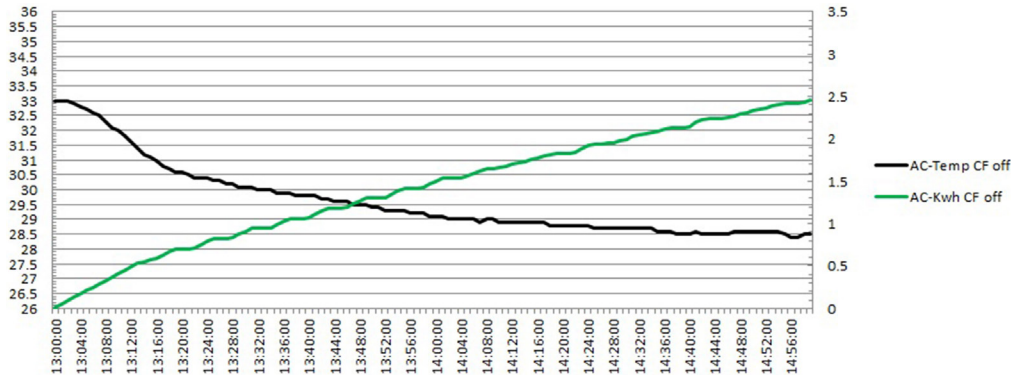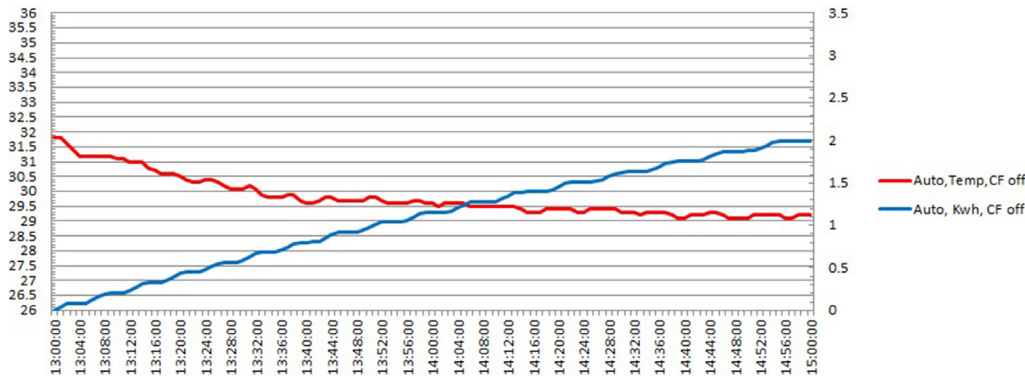
to select the most suitable mode for the next step order placing, therefore, this research attempted to explore how to use the current transmitter to let the AC knows that the temperature has been reached as well as what's next step it should operate in order to achieved the objectives of energy saving and comfy.

EXPERIMENTAL PROCEDURE AND RESULTS

As the AC used in this lab. was a fixed-frequency split air-conditioning being used for five years, in order to confirm whether the use of intelligent control of energy efficiency is achieved as expected, this study first carried out the multi-day tests and records for the AC mode controlled by remote controller and automatic mode. Owing to the unstable temperatures of spring season during the experimental period which gradually became warming, in order to obtain a more objective analysis of the data, this study set the value at room temperature of 26 °C and implemented four days' records and observed the temperatures and energy saving effects on the above-mentioned two air conditioning modes, then explored the indoor ceiling fan impact on AC effect on the basis of data test. The gateway controller used in our laboratory was able to record indoor temperature and total electricity consumption every minute. The findings showed that, under the condition of indoor fan shut down as well at the temperature of 26 °C, the room temperature was only reduced to 28.5 °C and 29.2 °C, respectively (Figures 3 and 4). Moreover, despite the air conditioner au-

Figure 5
The measured indoor temperatures and energy consumptions of AC mode combining with ceiling fan on May 14.
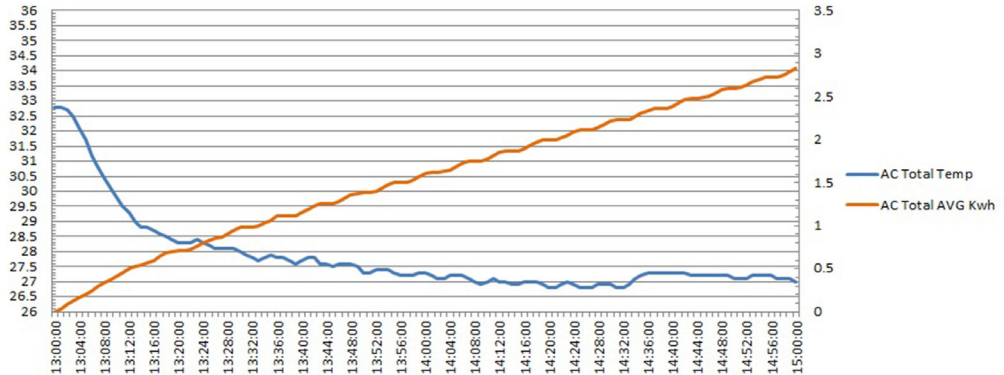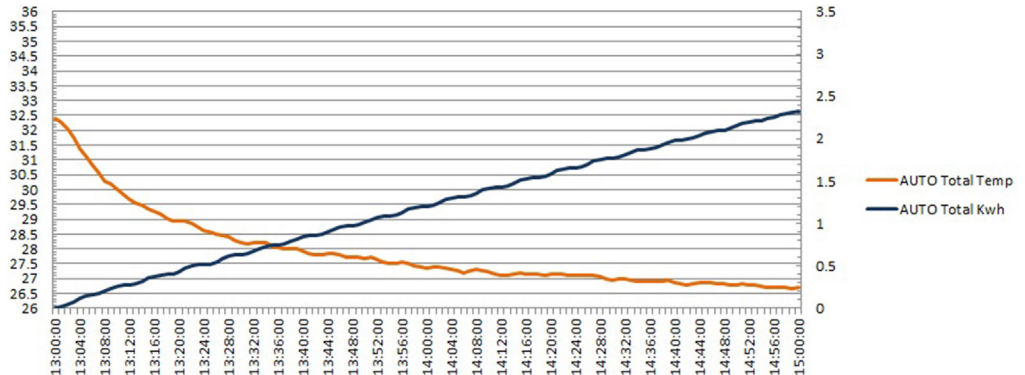

Figure 6
The measured indoor temperatures and energy consumptions of AC automatic mode combining with ceiling fan on May 14.

tomatic mode reached the energy consumption of 1.995kw in 2 hours, the quality of the indoor temperature cannot achieve the desired comfort.

After opening the indoor ceiling fans to help improve indoor air circulation under the same AC and automatic AC mode at temperature of 26 ℃, the room temperature value showed a significant improvement trend (Figures 5, 6).

Test results of these few days revealed that the split air conditioner in our study neither could reach desired temperature within two hours nor reduce the indoor temperature to a reasonable value, despite that indoor temperature showed a dropping trend. This phenomenon showed that the air temperature sensor was located in a place which was not able to detect the room temperature value cor-

rectly, resulting in the AC failed to carry out proper cooling effect in accordance with the actual indoor temperature value.

While coupling with the ceiling fan under the same set, value of the room temperature improved significantly and the indoor temperature was fairly satisfied -though not reaching but was closing to the set temperature of 26 ℃.

Based on the AC automatic mode and its achievable target temperature values, this study set different smart modes for the controller to test and record the AC's energy consumption situation.

- The temperature was set at 26 ℃ and the gateway controller would transmit message to AC to change the mode to fan mode when the room temperature reached 26 ℃, or restarted
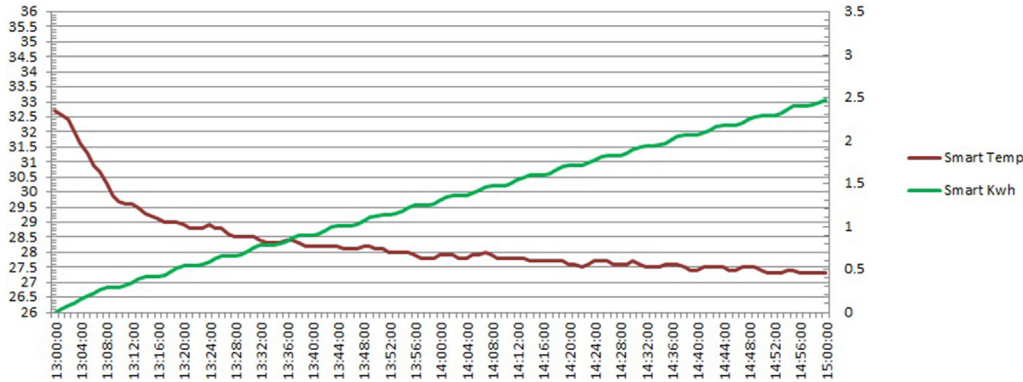
the AC compressor when the indoor temperature rose to 27 °C, so the cycle execution. The initial findings showed that, although the temperature was set at 26 °C, the indoor temperature was unable to cool down to 26 °C. Two possibilities are judged for such condition: A. Sensor mounted on the AC was too close to the outlet which led too high return cool air rate, thus causing the inconsistency between the temperature detected by the sensor and actual indoor temperature and resulting in automatic control mode failed to perform its function. B. The variation of detected temperature between sensor of this study and sensor mounted on the AC. After examination, it was found that there was 1°C difference between both sensors which led both operating modes of two hours test to exert the same effectiveness (Figure 7).

• The temperature of AC was set at 24 °C. When room temperature reached 24 °C, the AC would be ordered to change into fan mode, and would restart when indoor temperature rose to 27 °C. The results of measured data showed that, indoor temperature dropped from original 33.5 °C to 29.5 °C within ten minutes, but then gradually cooled to 27.5 °C in the rest 110 minutes (Figure 8), failing to reach the expected set temperature. The observations made here for such condition were that, in order to avoid excess use of AC, both ACs used by classrooms and lab. were adjusted and set. Therefore, no matter how the air temperatures

were adjusted, the compressor would maintain a certain operation mode which was difficult to change.

Experimental data showed that, as the intelligent control mode could only be operated by cool and fan modes which limited its compressor operation in terms of cooling and electricity consumption adjustment, its electricity consumption was almost the same as that of automatic AC. On the other hand, due to the operation mode of AC used by the school was adjusted before installation for the purpose of energy saving, it was incapable to reach expected temperature through the temperature adjustment.

Furthermore, the data also indicated that, without the ceiling fan to adjust air flow, indoor temperature was not only difficult to low down, but with significant fluctuation as well. Therefore, it is obvious that ceiling fan does help the indoor temperature to cool down.

CONCLUSION

The lab was constructed in winter time December, 2012, but did not start carrying out the experiment until the mid-April of next year when the weather was getting warmer. During the experimental period, this study discovered that when the initial indoor temperature became higher, the electricity consumption was also affected. However, the preliminary findings showed that the current operating mode of fixed-frequency AC was difficult to achieve the objective of energy saving through control method of smart system. Therefore, it is recommended that the future study should focus the application of smart control on AC with variable frequency in order to find out possible smart control mode to meet the demand for energy saving.

Owing to the shorter experimental period, the accumulated data of initial room temperature values in this study were rather limited and cannot be regarded as objective data to present the relationship of electricity consumption effectiveness between the indoor temperature and AC operation. This research will continue to apply different AC operating modes as well as statistical analysis to explore the relationship between the temperature of AC operation and electricity consumption, in order to identify the most energy-efficient mode of operation as a reference for future smart control studies.

The AC currently used by school have been adjusted which are not suitable for the test of energy consumption through temperature control of smart mode. However, as now the school has approved to have the lab AC restored to their original setting condition, the related experimental modes of this study will be continuously conducted in order to obtain more objective experimental data for the references of indoor temperature quality control and adjustment.

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